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Correlation of Laboratory Abrasion Testers

May 17, 1963

Dear Sir:

Investigations have been made to discover useful correlations among laboratory abrasion testing instruments and also between laboratory abrasion instruments and field wear [4, 9]. While these efforts have not been completely successful, the data obtained have provided a better understanding of some of the problems involved. The introduction and wide use of new man-made fibers have directed a significant amount of attention to the abrasion characteristics of fabrics and blends of man-made fibers. The attractive properties of such fabrics, particularly their functional properties, have created considerable interest among the military departments in performance as related to durability and

TABLE I. Composition of Fabrics

Fiber content, %	Fabric weight, oz/yd²	Type
Plain weaves		
Acrylic Z—100	8.1	
Modified nylon—100	7.9	
Polyester D (fil)—100	7.7	
Nytril D—100	7.7	
Modacrylic—100	6.8	
Polyester K—100	4.1	
Cotton warp, modified nylon filling	8.5	
Modacrylic—50 Nylon—50	8.0	
Cotton—50 Acrylic Z—50	7.6	
Cotton—50 Nytril D—50	7.4	
Sateen weaves		
Cotton—100	8.5	
Cotton—70 Nylon—30	8.5	
Polyester D (fil) warp Acrylic O filling	8.0	
Twill weaves		*Type*
Triacetate—40 Polyester F—30 Viscose—30	8.7	2/1 RH Twill
Polyester D—50 Cotton—50	6.7	2/1 LH Twill

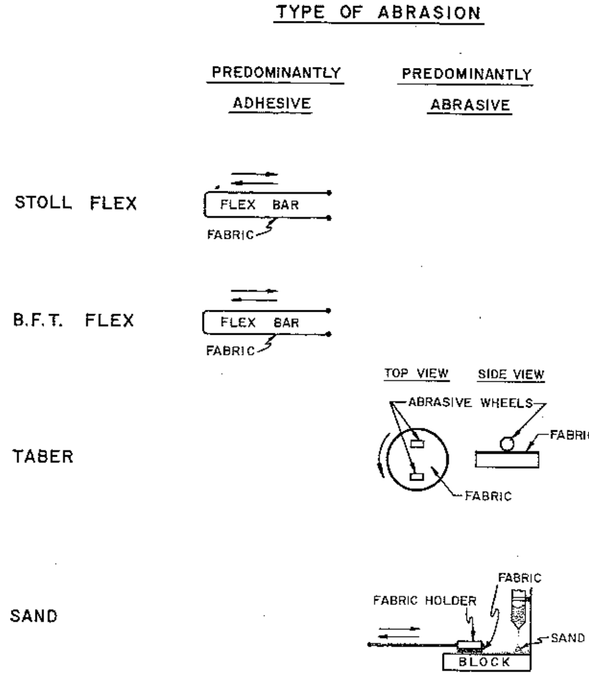

Fig. 1. Mechanism of action of abraders.

serviceability [7]. One of the early systematic studies of the abrasion characteristics of man-made fibers was that of Hamburger [3], who showed that work-to-rupture is an important factor governing the abrasion resistance of different fiber species; he obtained an excellent relationship between durability coefficients and energy coefficients for a number of different materials.

A study of the abrasion resistance of 15 prototype fabrics representing single-fiber constructions and blends of 12 different fibers is now underway at the U. S. Army Natick Laboratories. The purpose of evaluating this group of fabrics is to obtain a pattern of performance which may be relatable to the inherent mechanical and structural properties of the fibers and fabrics. The data presented here represent an interesting by-product of this study: a demonstration of the correlation among the several laboratory instruments used for evaluating abrasion resistance. The fabrics used in this study are listed in Table I.

It may be seen from Table I that these fabrics contain most of the generic groups of fibers designated by the Federal Trade Commission rules. In addition, they include both filament and spun yarn constructions in blends and in 100% single-fiber composition. Several weave types and fabric weights are represented. The samples were all tested with the fabric back adjacent to the abradant in order to make the results consistent with those obtained on the standard 8.8-oz carded cotton sateen, which is normally used with the back of the fabric to the outside of the garment. The fabrics were evaluated on the Stoll [6], Bocking (BFT) [2], Sand [8], and Taber [6] abraders. Warp direction samples were used but, since the mechanical action on the Taber is multi-directional, both yarn directions were subjected to abrasion. Figure 1 demonstrates the essential differences in the mechanical action of the four machines.

In planning this correlation study, recognition was given to a possible association between the action of these machines and the two types of metal wear designated as adhesive and abrasive. These two types of wear form the basis of two theories that have been widely reported in the literature. In the "adhesive" theory of wear proposed by Archard [1], molecular interactions that occur between asperities at the surface of the material being abraded and the abradant lead to the formation of molecular welds. These welds are sheared by the relative motion of the surfaces, thus producing wear particles. Since this is a surface phenomenon, adhesive wear is significantly reduced by the presence of boundary lubricants. The theory of "abrasive" wear, as presented by Rabinowicz [5], involves an actual penetration of the surface of the material by abradant particles. The relative motion of these surfaces results in a ploughing out of abraded substance. Since

TABLE II. Correlation Coefficients (R)

	BFT	Stoll	Taber
Stoll	0.95		
Taber	0.57	0.64	
Sand	0.63	0.74	0.86

TABLE III. Percent of Variance Explained by Interrelationships

	BFT	Stoll	Taber
Stoll	91.0		
Taber	32.7	41.2	
Sand	40.3	54.4	74.0

the surface is penetrated by the abradant, this type of abrasion is relatively insensitive to the presence of lubricants. The physical nature of the abrading surface in the Stoll and BFT abraders, coupled with the marked sensitivity of abrasion results on these machines to the presence or absence of lubricants, suggests that their abrasive action is of the "adhesive" type. On the other hand, the nature of the abradant in the Sand and Taber instruments, when considered in conjunction with their relative insensitivity to the presence of a lubricant in the fabric, suggests that their action is "abrasive."

The end point of tests on the Stoll and BFT abraders is the number of cycles to rupture. This is an objective point and requires no interpretation on the part of the operator. The end point of tests on the Sand and Taber abraders is the number of cycles to produce a predetermined level of apparent damage as assessed by visual examination. This is a subjective point that can vary from operator to operator. In this study, determination of the end point on the Taber and Sand abraders was made by one operator in order to obtain consistent results among the samples.

The data obtained were subjected to statistical analysis: computation of correlation coefficients and percent of the variance explained by the interrelationship among the instruments. The correlation coefficients and explainable variance are shown in Tables II and III.

As was expected, the closest relationships were obtained between the BFT and Stoll, with an "R" value of 0.95, and between the Sand and the Taber, with an "R" value of 0.86. Ninety-one percent of the variance can be explained by the interrelationship between the BFT and Stoll, whereas 74% of the variance can be explained by the interrelationship between the Sand and the Taber. The difference between 91% and 74% suggests that the physical basis for the correlation between the BFT and Stoll is more valid than that between the Sand and the Taber. The correlation coefficients between those instruments producing adhesive wear (Stoll and BFT) and those producing abrasive wear (Sand and Taber) range from 0.57 to 0.74; the explainable percent of variance for the same instruments range from 32 to 54.

Plots of BFT versus Stoll and Sand versus Taber are shown in Figures 2 and 3.

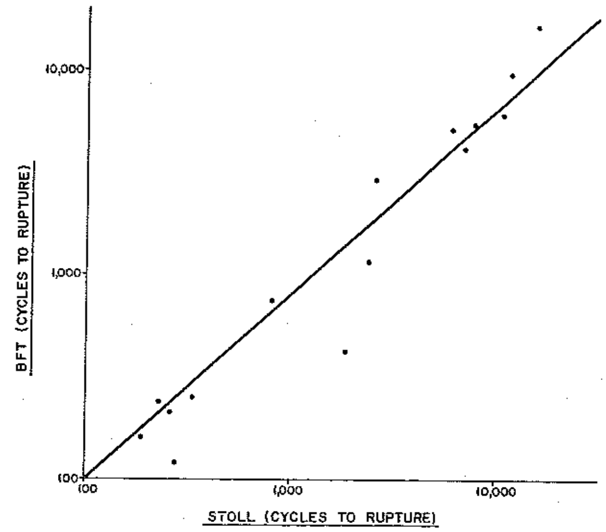

Fig. 2. Comparison of BFT and Stoll abrasion.

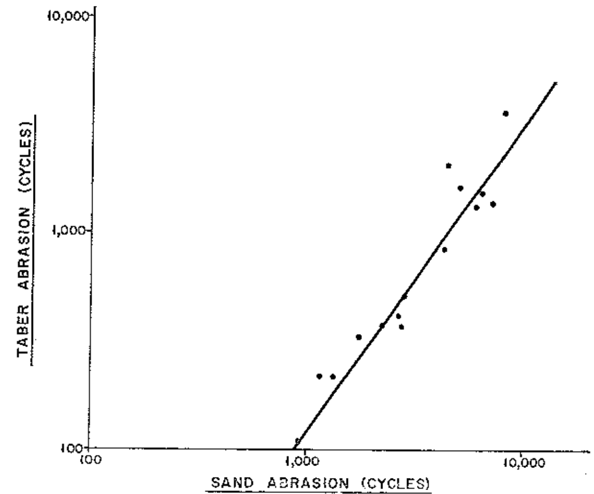

Fig. 3. Comparison of Sand and Taber abrasion.

The results of this study suggest that differences in types of wear action have a significant influence on the correlation of laboratory abrasion instruments. Those instruments which produce similar types of wear correlate within rather close tolerance limits. Correlations of these types prove to be quite useful in laboratory wear studies. For example, the BFT abrader produces a much more rapid rate of abrasion than does the Stoll; it is therefore more efficient and economical to use the BFT when it is desired to obtain an indication of the specific type of wear action characteristic of these two abraders.

The results of this study also make it appear advisable to re-examine the basic wear actions of the various types of abrasion machines currently used for textile materials. It is possible that the results on one or more of the abraders that produce a relatively simple mechanical action may be relatable to the more complex types of wear that are observed in the use of garments by the consumer.

Further, this study suggests the need for developing objective end points for instruments that produce an abrasive type of wear. Abrasive wear generally appears to predominate in the field use of combat, utility, and work clothing.

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